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ABSTRACT

Part of a series of eight student learning modules in vocational agriculture, this booklet deals with plant reproduction. Topics covered include the pure line theory and its history, pure line selection, the effect of inbreeding on vitality, the definition of and reasons for hybridization in plants, and techniques for producing hybirds; a list of hybrid crops is provided. Each of the two major sections concludes with a quiz on the material covered. (PLB)

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STUDENT MATERIALS

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MAINTAINING PURE LINES

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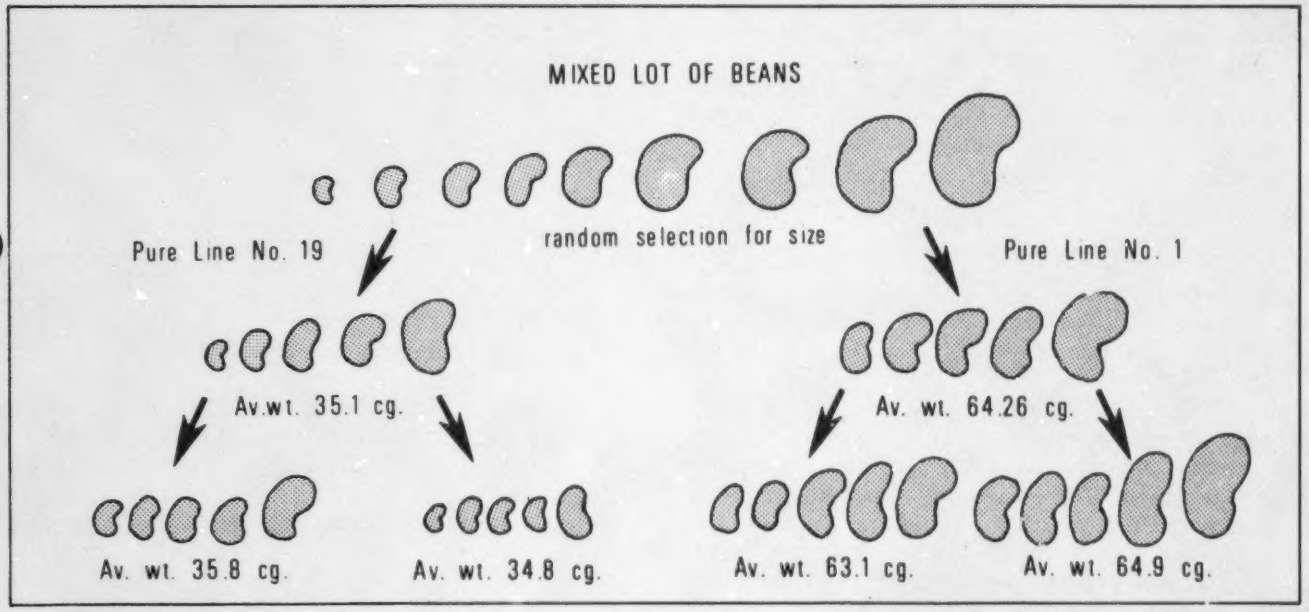
The pure line theory was established at the turn of the century by a Danish botanist by the name of Johannsen. He worked with mixed seed samples of the Princess bean to arrive at the theory in 1903. His experimental procedure was as follows:

> Seed lots of both large and small seed were selected at random, planted and harvested from each plant. All the seed were pure due to bean seed being self-fertilized, and they remained pure for conducting the experiments. Pure lines of large and small seed were selected. A total of nineteen pure lines were established of certain size beans from the mixed lots. Weight tests were used to prove that variations in seed size of large and small beans were due to environmental conditions in the beans producing area since the inherent characteristics were pure.

The following illustration shows a mixed lot of Princess beans with two pure lines being selected:



> Pure line No. 19 was selected and grown in isolation. These random selected beans produced seed similar to the parent line, weighing 35.1 centigrams in weight. Further selection of beans in this line produced beans with an average weight of 35.8 centigrams and 34.8 centigrams. The random selection of large seed produced an average weight of 64.26 centigrams, and the seed, both large and small produced 64.9 and 63.1 centigram average.

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Continuous selfing (self-pollinated) tends to produce plants that have all homozygous genes, which means the plant is inbred or a pure line. As demonstrated in the illustration, the mixed population of beans are inherently different in size, and the larger beans of pure line No. 19 produced lighter weight beans than the lighter weight beans of the large bean Line No. 1; therefore, further selected samples may not change the genotype of the pure line due to the inherent characteristic and new genotypes may not be created by pure line selection. Selection is made by isolation of the genotype present. For example, grain producers have noticed off-type plants in a field that carried desirable characteristics, so they selected those particular plants for seed. The seed from these plants are planted and tested before they are increased, named, and marketed.

Before Johannsen made his work known, early agriculturalists introduced new crops by selecting seed from

wild and cultivated plants and transplanting them in order that the crop plant or plants could be cultivated. From these cultivated plants the crop producer continued to select seed or plants that best served the needs. Seeds and seedlings were selected that survived droughts, suffered less insect and disease damage, and produced high quality food or feed. This method of plant improvement continued until Mendel worked out his laws of heredity in the mid-19th century. His work went unnoticed until the 1900's. Mendel's work was with peas which are considered pure due to self-pollination.

There are several factors that affect pure lines. Some of these factors are:

The crop's genetic stability
The amount of cross-pollination
The ca. e of the crop while it is being produced

Naturally, pure lines become impure when seed from other varieties are mixed with pure line seed, when natural crossing takes place, and when mutations form. Pure line crop varieties were originally produced to give a uniform appearance and in some cases a uniform taste and a general uniform performance. In recent years less emphasis has been placed on complete uniformity.

A pure line variety may be defined as a variety that consists of the genetically identical progeny (offspring) of a single, self-fertilized, homozygous plant. Identical genes are transmitted by such individual plants through their germ cells; this causes all the offspring to be identical to the parent plant and to each other. A purebred self-pollinated plant breeds true.

The systematic improvement of plants through plant breeding did not become a reality until the 20th century. Even though the Old World (China, South Asia, Central Asia, Asia Minor, Mediterranean Area, and Abyssinia) domesticated approximately five-sixths of all species of cultivated plants, the New World (North America, Central America, and South America) has worked extensively to improve the remaining one-sixth of the cultivated plants which were found in the New World. Since the colonists landed on Plymouth Rock, the western world has continued to introduce cultivated plants from the Old World.

Pure Line Selection

Many plant varieties have been produced by pure line testing and selection methods. Progeny tests follow pure line selection in order to determine whether or not the plant has the desirable characteristics for future production. In progeny testing, the individual plant's performance can be observed and studied.

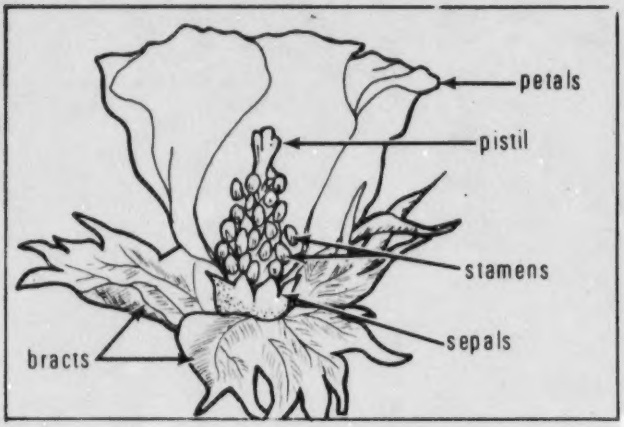
The main reason for selecting plants is to preserve the desirable characteristics and eliminate the undesirable traits or characteristics. Until recently the farmer and plant breeder developed all plants along pure-line varieties. Most crops are still marketed according to appearance and other standards; therefore, it is necessary to maintain pure-line varieties in certain crops in order to produce uniformity, texture, firmness, and other grade standard qualities. In some cases multiple or mixed varieties are developed for the following reasons:

To produce better yields under adverse climatic conditions.
To give better protection against insects and diseases.
To produce a raw material that is easily harvested.
To grow plants that will produce on different types of soils.

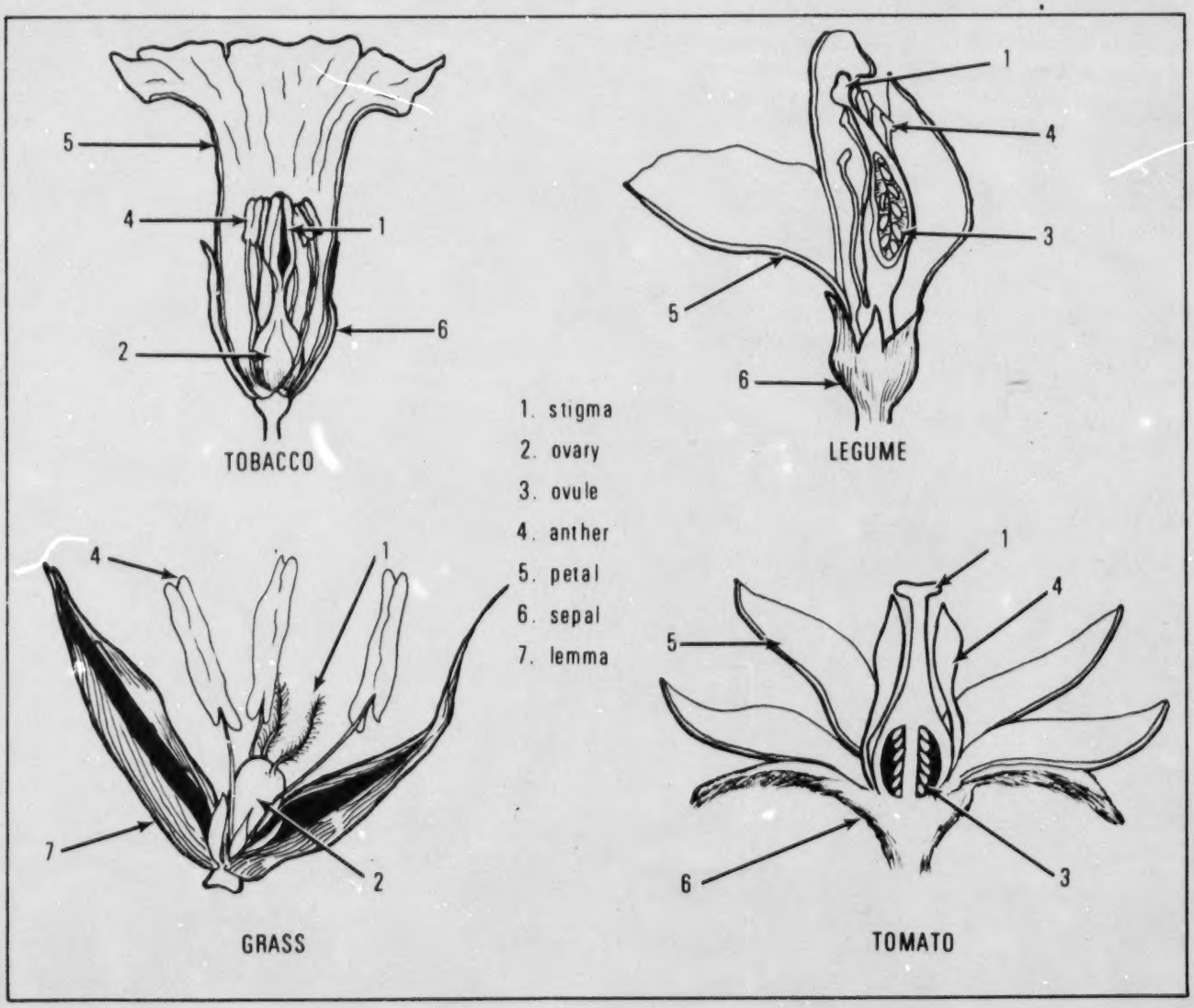
Pure lines are developed for the purpose of breeding true characteristics in plants. Example: F_1 hybrids are produced by using two pure-line parents. The characteristics that remained pure by continuous inbreeding are transmitted from the parents to the offsprings by gametes (germ cells). Before crossing two pure-lines to produce an F_1 hybrid or cross, it is very important to select parent plants with desirable traits.

Pollination of Crop Plants

Crops such as wheat, oats, barley, rye, rice, flax, soybeans, peas, and beans are self-pollinated. They are usually easily maintained as pure lines or pure varieties due to characteristics of the plant. These crop plants remain mostly pure when grown in close proximity of closely related or similar varieties. Such plants as corn, cotton, and grain sorghum must be isolated if they are to remain pure. The floral parts of these plants must be covered to protect the plant from foreign pollen; otherwise, cross-pollination may occur. A pure line of soy-



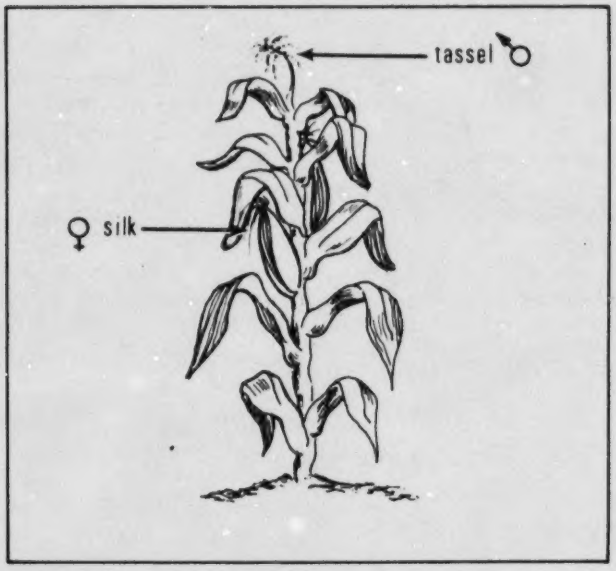
beans may remain pure, but a pure line of cotton can become impure due to cross-pollination from other cotton plants, even though the cotton flower is mostly self-pollinated. Each flower contains stamens and a pistil that is surrounded by three triangular bracts which form the squares. A tube is formed by the stamens that encloses the style which is united with the inside base of the corolla. Anthers open and shed pollen directly on the stigma. Cotton pollen is considered to be heavy and sticky; therefore, cross-pollination depends mainly on insects. Some other types of flowers that are self-pollinated are as follows:



Both tobacco and legume flowers are better protected from foreign pollen than cotton, grass, and tomato flowers.

With crops that are completely self-fertilized, it is not necessary to reselect for plant characteristics because selfed plants will remain pure unless mutations occur. New genotypes (heredity makeup of an individual plant,

combined with the environment, controls characteristics) are not developed through pure-line selection; the genotype is already present in the plant population. Self-pollinated plants used for crossing and for pure breeding crop production are usually considered approximately 95 percent pure. Through proper management, self-pollinated plants can be kept pure for breeding purposes. The seed of a self-pollinated plant is used each year for reproduction purposes, whereas new cross-pollinated hybrid seed must be used each year.



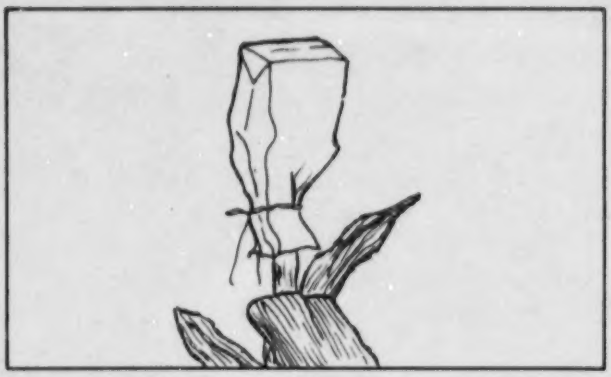
Selfed (self-pollinated) refers to a plant where the pistil part of the flower is fertilized with pollen from the same plant that bears the pistil. Inbreeding plants is usually accomplished by self-pollination. This type of plant breeding improves the homogeneity. The number of heterozygous genes are reduced in selfing.

Cotton, sorghums, and sudangrass are crops that vary in methods of field crop pollination. The species in this group of plants have perfect flowers, and the receptive stigma may be exposed to cross- and self-pollination. Wind causes cross-pollination in sorghum, and insects cause cross-pollination in cotton.

The reason that many legume plants such as clovers, beans, and peas breed true is that the stigma and other floral parts are protected from foreign pollen by the petals and sepals. Some plant flowers are only partially protected from foreign pollen, as in the case of tobacco. If the flower is to be 100 percent self-pollinated, the floral parts must be covered with a bag. Corn can be selfed (self-pollinated) because the male part (tassel) and female part (silk) are on the same plant. The only safe way to self-fertilize or self-pollinate corn is to protect the female part. Self-pollinating steps used on corn are:

Cover the ear shoot with a glassine bag before the silks appear to protect them from pollen that may be scattered by the wind.

Two days before pollination remove two or three inches of the tip of the ear shoot and bag the ear the second time.



Place a paper bag over the tassel the day before pollinating the ear shoot.

Remove the bag from the ear shoot, collect pollen in the tassel bag, and dust it on the silk brush of the ear shoot. Retie the bag over the ear shoot to protect it from foreign pollen.

Many crop plants that are normally cross-pollinated can be self-pollinated artificially, in order to develop pure lines. Continuous inbreeding of cross-fertilized crops will eventually cause a loss of plant vigor in some of the plant traits or characteristics. The abnormalities that may appear are:

Lodging (bending or breaking over) in grains
Lack of chlorophyll development
Low production
Sterility
Dwarfness
Susceptibility to diseases
Lethal seeding

VITALITY AFFECTED BY INBREEDING

Plant vitality begins to decrease in onions after they have been inbred for about three years.

1 2 3 4 5 6 7

The sorghum crops seem to maintain plant vigor even after as much as twelve years of inbreeding.

1 2 3 4 5 6 7 8 9 10 11 12

Cotton seems to lose plant vigor after about four years of plant inbreeding.

1 2 3 4 5 6 7 8 9

Corn may begin to lose plant vigor after about five or six years of inbreeding.

1 2 3 4 5 6 7 8 9 10

Inbreeding may cause the recessive characteristics to come forward which may be desirable when breeding some plants.

SUGGESTED STUDENT ACTIVITIES

1. Completion

   a. The pure line theory was established by _____.
   b. A pure line of cotton may become impure due to _____-pollination.
   c. A systematic approach to plant breeding became a reality at the beginning of the _____ century.
   d. Inbreeding of plants is usually accomplished by _____-pollination.
   e. Cross-pollination in cotton is caused mainly by _____ due to the pollen being heavy and sticky.
   f. The male part of a corn plant is known as the _____.
   g. The only safe way to self-fertilize corn is to protect the _____ part of the plant.
   h. Cotton seems to lose its plant vigor after about _____ years of plant inbreeding.
   i. Self-pollinated plants used for crossing and for pure breeding are approximately _____ percent pure.
   j. Continuous selfing tends to produce _____ genes.

2. List and discuss the steps used in self-pollinating corn.

   a.

   b.

   c.

   d.

3. Define the following terms:

a. Lodging -

b. Pure line variety -

c. Self-pollinated -

d. Cross-pollinated -

e. Genotype -

4. Discuss the following questions:

a. Johannsen's experimental procedure with samples of the Princess bean.

b. Continuous selfing.

c. How pure lines become impure.

d. The main reason for selecting plants.

e. How the vitality of a sorghum plant is affected by inbreeding.

5. Underline the word True if the statement is true or underline the word False if the statement is false.

a. Excessive amount of cross-pollination does not necessarily affect pure lines. True or False?
b. The new plant world is considered to be Central and South America. True or False?
c. Cotton is cross-pollinated mainly by insects. True or False?
d. Continuous selfing tends to produce plants of nonhomozygous genes. True or False?
e. Pure line crop varieties were originally produced to give a uniform appearance. True or False?

f. In recent years more emphasis has been placed on complete uniformity. True or False?
g. F_1 hybrids are produced by using one pure line and one impure line parent. True or False?
h. It is easier to produce pure line beans than tomatoes. True or False?
i. With crops that are completely self-fertilized, it is necessary to reselect for plant characteristics. True or False?
j. Cotton seems to lose its plant vigor after about seven years of continuous inbreeding. True or False?

NOTES

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STUDENT MATERIALS

HYBRIDIZATION

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Early Improvements of Crop Plants

Plant life is the basis of all life on earth. Animal life would cease to exist if all plant life were suddenly destroyed. Food that supports and maintains animal life comes from plants, either directly or indirectly. Proper management of crop plants is the basis for human sustenance.

Plant taxonomy and plant physiology became major parts of the plant sciences during the Eighteenth Century. Before the Sixteenth Century, crossbreeding, inbreeding, and selection of plants were done by nature; the only plants that survived were those that could withstand the hazards of the environment. Man took many years to discover that certain plants were useful to him and by gathering the best seeds for planting, he could better feed and clothe his family. Crude as it was, this was the beginning of plant improvement; however, little progress was made until Gregor Mendel, the Austrian monk, discovered the laws of heredity. Mendel was one of the earliest recognized hybridizers. His experimental findings on breeding garden peas were published in 1866. In 1900, Mendel's report was of value in developing a branch of science known as genetics. The report on his experiments was instrumental in establishing a few principles of inheritance that are used in modern-day plant breeding techniques.

As a result of discovering Mendel's work on plant breeding, experiments were started in 1904, by breeding strains of corn. When single inbred lines of corn were crossed, they produced a more productive and vigorous plant than the parent plants. This single cross was known as hybrid corn.

Meaning and Reasons for Hybridization in Plants

Hybridization is the crossing of plants of unlike genetic makeup. It is also a method of breeding new plant varieties that requires crossing to obtain the best qualities of the parent plant characteristics in a single strain of plants.

The reasons for hybridization are:

One of the main reasons for hybridization is to get hybrid vigor or heterosis. The hybrid has more vigor than the parent plant. Crossbreeding usually strengthens plant characteristics. Some desirable qualities can only be developed by crossbreeding or hybridization.

Hybridization may increase yields and improve the quality of produce harvested from a crop by combining the characteristics of two plants.

Disease and insect resistant plants may be obtained from this process of plant breeding.

Another reason for hybridization is to develop plants for better climate adaptation.

It is used to combine all the desirable characteristics in crop plants. For example, if variety A corn is crossed with variety B corn, the plant breeder would look for the following:

Variety A	+	Variety B
Excellent quality grain		Fair quality grain
Weak stalk		Strong stalk
Resistant to smut		Susceptible to smut
Resistant to drouth		Susceptible to drouth

Results
Excellent quality grain
Strong stalk
Resistant to smut
Resistant to drouth

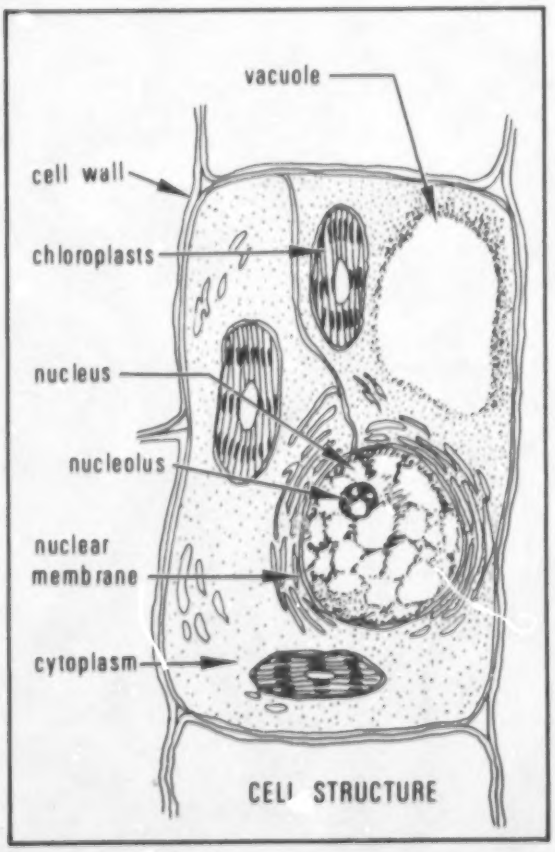
When variety C is crossed with D, the desirable qualities or results should be:

Variety C	+	Variety D
Fair quality grain		Good quality grain
Strong stalk		Weak stalk
Susceptible to smut		Resistant to smut
Resistant to drouth		Susceptible to drouth

Results
Good quality grain
Strong stalk
Resistant to smut
Resistant to drouth

As stated previously, corn carries 20 chromosomes; 10 are male and 10 are female. If ABCDE carry the characteristic for good yields, and inbred A genotype AABBccddEE with ABE being dominant plus inbred B genotype aabbCCDDEE with CDE being dominant, then the genotype F_1 hybrid would be AaBbCcDdEE. In that the F_1 hybrid has dominant genes ABCDE represented, it becomes more vigorous than either of the parent inbred lines. Usually only the dominant characteristics are produced in the F_1 generation. In the F_2 generation both dominant and recessive characteristics are expressed.

The Plant Cell Structure



Plant cells are of many types and have many functions. The entire structural unit of a plant consists of cells. The plant characteristics are determined by what happens when the male cells unite with the female cells which is known as fertilization. Through hybridization there may be a change in the food making, support, food conducting, absorption, and food storage cells. In most plants, cells cannot be seen by the naked eye and after they are magnified they may appear as rods or spheres. However, some nonreproductive cells in green algae may exceed an inch in length. The smallest form of plant cells are bacteria. Usually the cell structure of a plant is divided into three general groups: the cell wall, protoplast (living parts of the cell) and orgastic substances (nonliving components of protoplast). Types of nuclear division occurring in the cell are discussed under the heading Nuclear Division.

The nucleus, a component of the protoplasm, may appear as an elongated, spherical or ovoid structure. This important part of the cell is embedded in the cytoplasm. The nucleus contains the nucleolus (photoplasmic body) and chromatin (hereditary material), and actually the control of the center of a cell. Apart from the nucleus in the cell are chloroplasts (specialized plastids containing color or chlorophyll). They serve as a functional unit of photosynthesis.

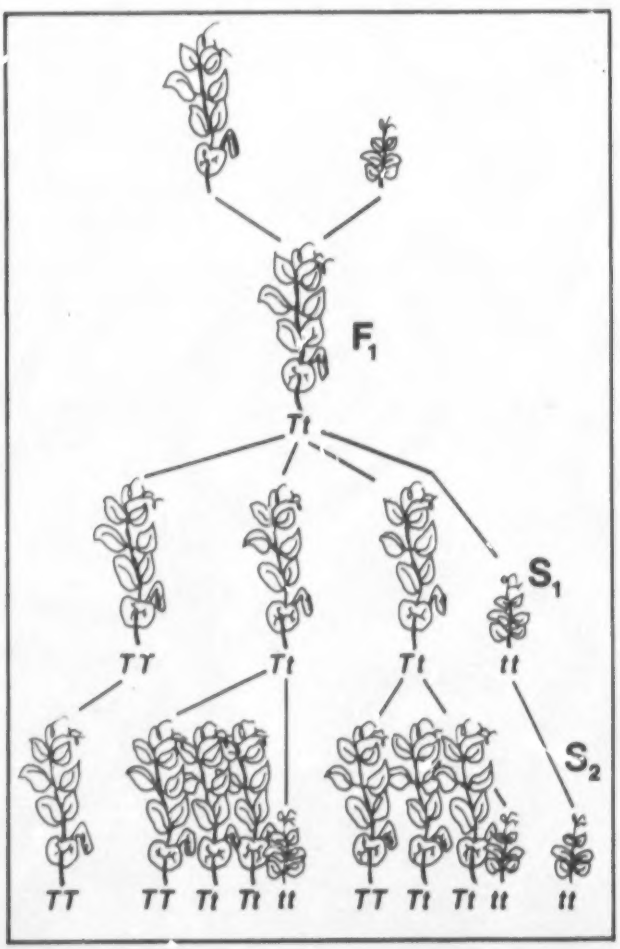
How the Plant Acquires Certain Characteristics

Each plant has a certain number of chromosomes which are contained in the nucleus. Chromosomes are usually rod-like or thread-like bodies that carry genes arranged in linear order. These genes which are located on the chromosomes determine the characteristics or traits of a plant.

The same number of chromosomes are found in the male and female cells (gametes). Chromosome pairs are formed when the male and female chromosomes unite. For example, corn carries 20 chromosomes; 10 are male and 10 are female. At the time of fertilization 10 pairs are formed. If the genes are identically paired (dominant and recessive) on the chromosome pair, the traits of the plant will be true breeding or homozygous. If the chromosome carries both dominant and recessive or dissimilar genes for the same traits or characteristics, then the plant will not be true breeding for those specific traits and is considered to be heterozygous.

The characteristics supplied by the genes (a unit causing inheritance characteristics located on the chromosome) determines what the plant will be like. The dominant and recessive traits are identified as follows by large and small letters:

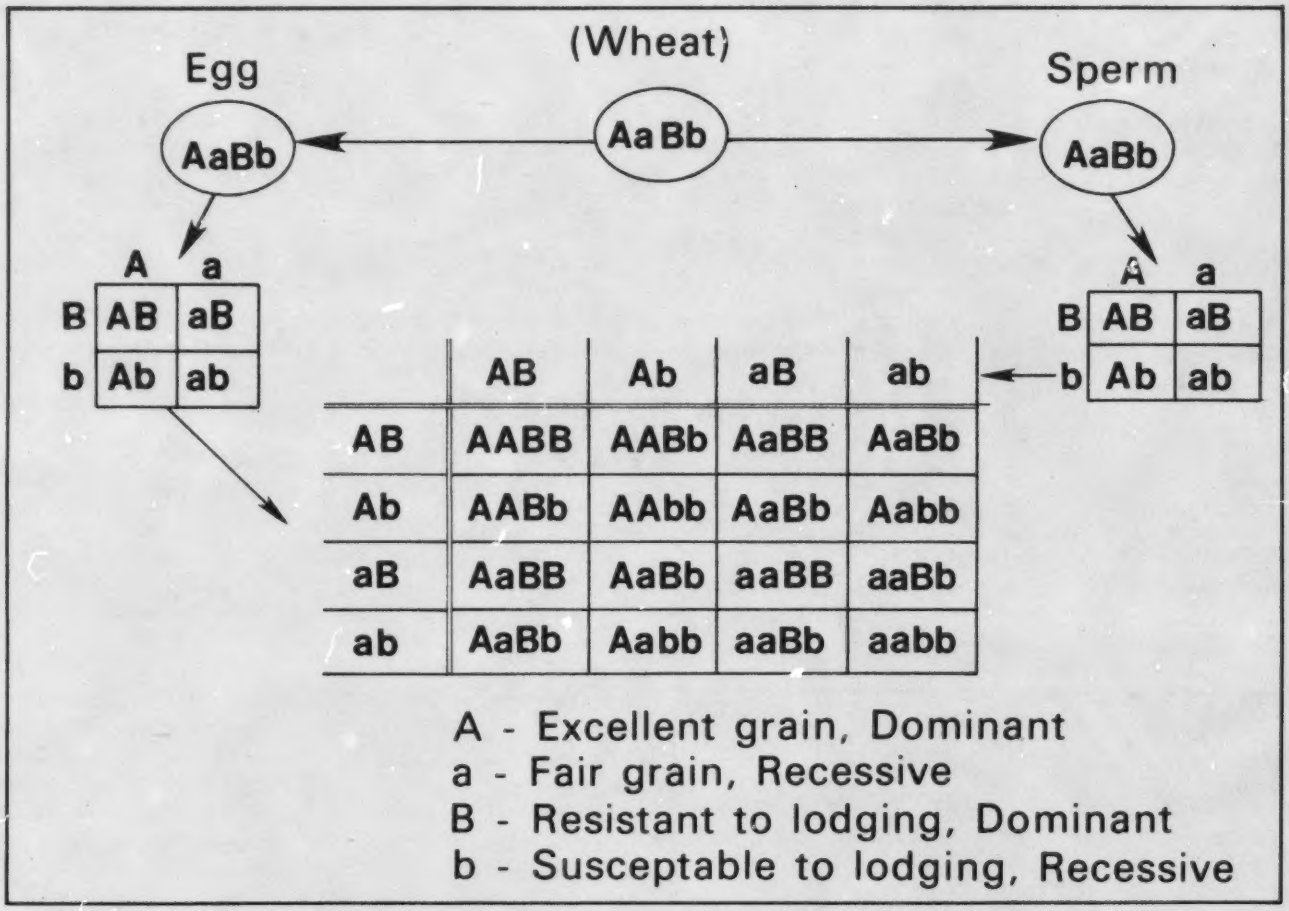
E	e	Ee
S	S	SS
w	w	ww
Male chromosome with two dominant and one recessive gene	Female chromosome with one dominant and two recessive genes	Male and female chromosomes united with two complete dominant and two recessive genes



The superior or dominant genes will usually appear as a plant characteristic whereas inferior or recessive genes will not usually appear as a plant characteristic, if the dominant gene is present. Example: If "E" represents excellent quality grain and a dominant characteristic in one plant and "e" represents fair quality grain and a recessive characteristic, and the two plants are crossed, the "Ee" first offspring will have excellent grain. Sometimes the gene is neither dominant nor recessive; therefore, when they occur in the same plant an intermediate characteristic is formed. Example: If we assume that A variety corn is crossed with B variety corn as explained under reasons for hybridization, then the results would be excellent to good quality corn.

Mendel's experiments with the garden pea proved that the F_1 hybrid (first filial generation) carried the dominant gene "T" that caused all the plants to be of the same genotype (Tt). Mendel used one parent generation (P_1) that was pure for tallness, and all the F_1 generation was tall. The first generation of inbreeding of the F_1 generation (Tt) from controlled self-pollination is designated as S_1 and the second S_2 . The S_1 corresponds to F_2 controlled hybridization. In the S_1 generation 75 percent of the plants were tall and 25 percent were dwarf. The ratio of tall plants to dwarf plants was 3:1. In the S_2 generation all the progeny of tall plants were tall and the dwarf plants dwarf. The phenotype (external appearance) of Mendel's peas was not always the same as the genotype (genetic constitution).

Gene pairing in double crossing of wheat is illustrated below:



When the parents of the F plants are homozygous (AAbb and aaBB) the gametes of any one parent have identical gene alleles. These genes combine to produce F_1 or heterozygous (AaBb) plants, which in the case of wheat is excellent grain and resistant to lodging because A and B are complete dominant characteristics. The egg and sperm (gametes) of the F_1 have four combinations of genes (AB, Ab, aB, and ab). When the four kinds of eggs are united with the four kinds of sperms, the combination of the genes will result in an F_2 phenotype with sixteen possible combinations. However, there are only nine genotypes and four phenotypes in this double cross. These types of combinations are:

Genotypes	Phenotypes
1/16 AABB 2/16 AABb 2/16 AaBB 4/16 AaBb	9/16 Excellent grain and resistant to lodging
1/16 AAbb 2/16 Aabb	3/16 Excellent grain and susceptible to lodging
1/16 aaBB 2/16 aaBb	3/16 Fair grain and resistant to lodging
1/16 aabb	1/16 Fair grain and susceptible to lodging

The combination is also listed as follows:

AABB
AABb
AaBB
AaBb
(9-excellent grain and resistant to lodging)

AABb
AaBb
AAbb
Aabb
(3-excellent grain and susceptible to lodging)

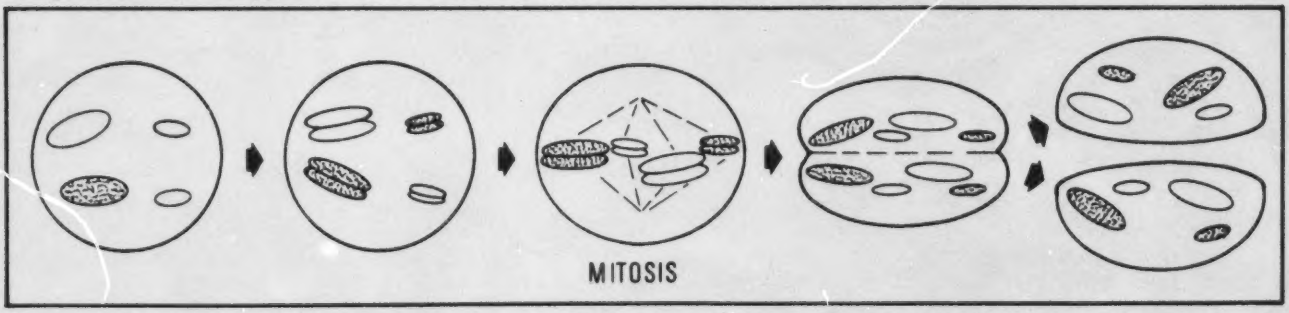
aaBB
aaBb
(3-fair grain and resistant to lodging)

aabb
(1-fair grain and susceptible to lodging)

The dihybrid cross (two traits) gives a 9:3:3:1 ratio in the F generation. The most desirable combination of genes produces a plant with excellent grain and resistant to lodging (AABB). The least desirable gene combination produces plants with fair grain and susceptible to lodging (aabb). These two combinations are considered to be homogenous, and will continue to reproduce like plants if self-pollinated.

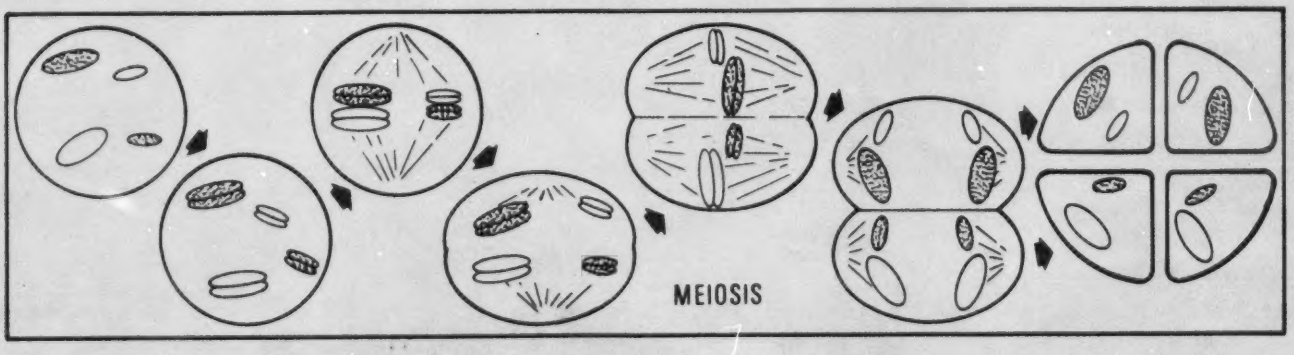
Nuclear Division In The Cell

There are two types of nuclear cell divisions occurring in the plant cell. They are mitosis and meiosis. The comparison of these types of division are illustrated in the two following diagrams:



In the mitosis process of cell division each chromosome splits longitudinally and forms two chromatids. The chromatids migrate in equal numbers to each of the poles. Two daughter cells or nuclei are formed that are similar to the parent cells and they are separated by a partitioning cell wall. This is the only form of cell division associated with asexual reproduction. The darkened chromosomes come from one parent and the shaded chromosomes from another parent. This method of division takes place in the growth and development of the plant.

The second form of cell division is associated with sexual reproduction. Several cell divisions take place in the formation of gametes. The cell divides twice and the chromosome once. Meiosis takes place in the division of the spore mother cells which divide to form the spores. The first division is reductional and the second equational. The process is illustrated and discussed as follows:



In meiosis there are two successive nuclear divisions. Those that contain genes with similar hereditary characteristics are paired (homologous chromosomes). The chromosomes with their chromatids joined together move to the equator of the spindle. The homologous chromosomes separate and a member of each pair moves to the poles. The four pairs of chromatids move to opposite poles; they divide the second time moving to opposite poles before the four daughter cells are formed, each with half the number of chromosomes as the parent cell. Meiosis maintains a stable number of chromosomes in a species. This prevents the number from doubling with each generation when the two gametes fuse. Chromosome number is reduced from the diploid (2n) in the mother cell to haploid (n) number in spores. When the sperm and egg fuse at the time of fertilization, the zygote has restored in it the diploid chromosome number. The triple fusion of polar nuclei and sperm forms the endosperm nucleus which has a triploid (3n) chromosome number.

The darkened chromosomes are from one parent and the light chromosomes from the other.

Producing Hybrid Corn

Hybrid corn seed was produced in quantity in Iowa in 1926. On a test and experimental basis, the first hybrid corn was produced in 1907. Several homozygous parent (P_1) lines were produced by self-pollination of plants. These lines were crossed with two different (P_1) lines to produce an F_1 hybrid generation. By 1933 only about one percent of the farmers in the corn belt were using hybrid seed. But, in 1955 almost 100 percent used hybrid seed corn. Within five years after hybrid grain sorghum seed became available, about seventy percent of all growers were using hybrid seed.

Hybrid seed is more difficult to produce than inbred (self-pollinated) or ordinary seed. Hybrid corn seed is one of the easiest hybrids to produce due to the male and female flowers being located on the same plant. However, the development of pure lines in corn has been more difficult than many other plants because of cross-pollination. It usually takes about five years to self-pollinate an inbred line of corn which can be used for crossbreeding. Usually plant vigor is lost due to inbreeding, but it is regained when the inbred lines are crossed with unrelated inbred lines to produce the F_1 progeny. During the inbreeding phase of producing hybrid corn, plants showing weak characteristics are discarded. Only the most productive and strongest inbred lines are used for seed production.

The steps involved in producing hybrid seed corn are as follows:

Select suitable strains of open pollinated varieties (two inbred lines with desirable characteristics) that have been inbred until they are considered to be genetically pure.

The three types of hybrids developed by using pure inbred lines are:

Single Hybrid
Plant A inbred x Plant B inbred
↓
AB - a single cross

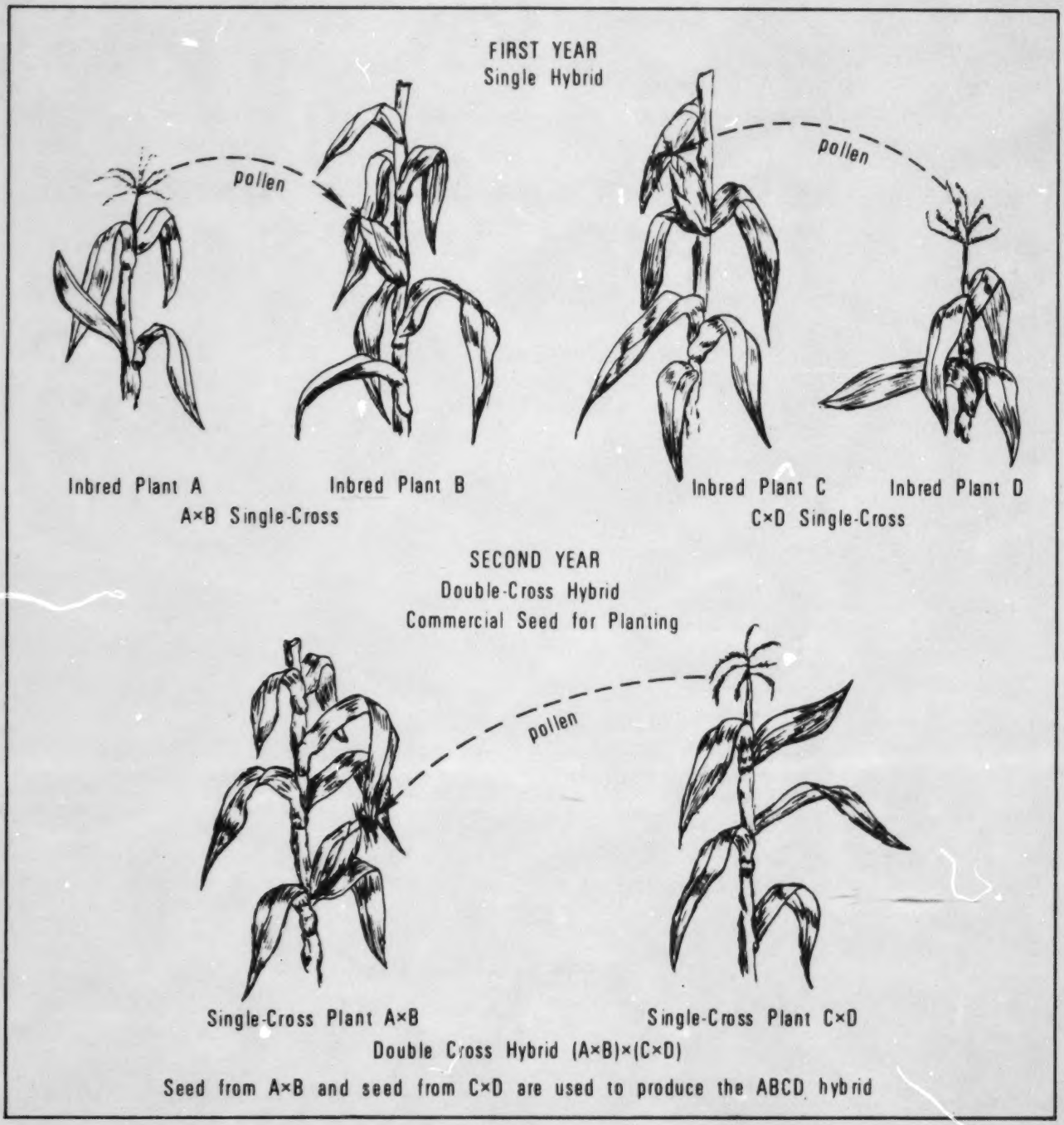
Three Way Hybrid
Plant A inbred x Plant B inbred
↓
Plant AB cross x Plant C inbred
↓
ABC - three way cross

Double or Four-Way Hybrid
Plant A inbred x Plant B inbred = Plant C inbred x Plant D inbred
↓
AB x CD
↓
ABCD - double cross

Most hybrid corn seed is produced from the double-cross.

When producing hybrids from a three-way or double-cross the A and B plants must be planted in a different field from the C and D plants. Naturally, the hybrids bear characteristics of the parent plants and if they are crossed with either parent plant, the progeny is called a backcross.

Illustrated below are methods used in producing hybrid corn and hybrid sorghum seed:



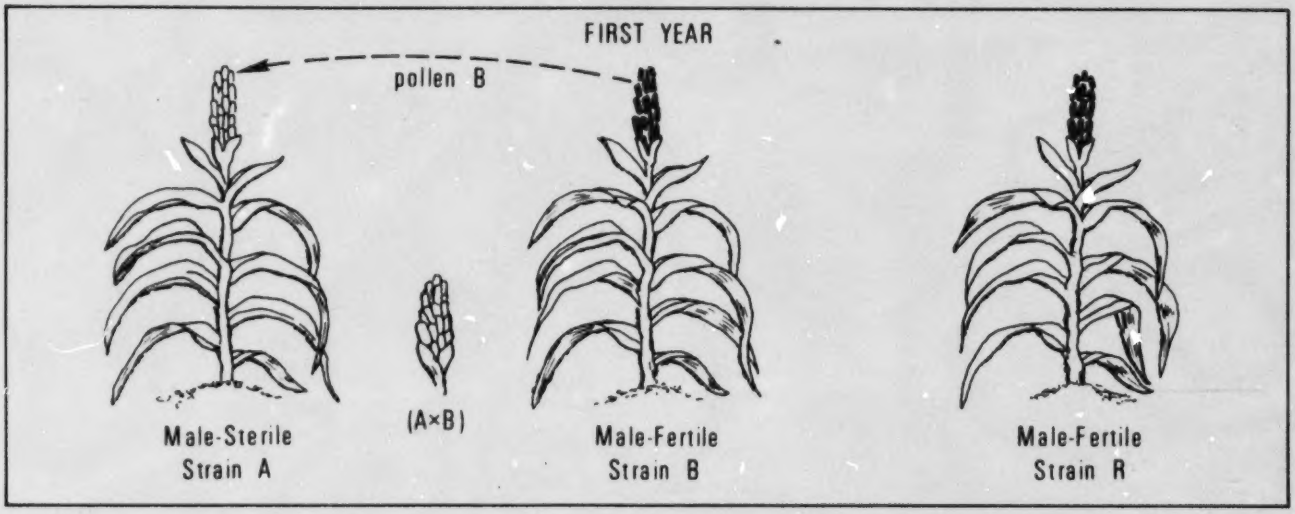
For seed production the F_1 generation of hybrid corn is produced by planting two rows of one inbred line beside one row of another line. The two rows are detasseled, and the one row retains its tassel for fertilization. A double or four-way hybrid is produced by planting six rows of one single hybrid and two rows of another single hybrid. The six rows are detasseled and are fertilized by the pollen from the tasseled two rows. In both single and double hybrid methods the detasseled corn is harvested for seed.

Plant breeders have developed special strains of male sterile inbred lines in sugar beets, barley, corn, sorghum and other crops. Male sterile plants produce no functional pollen; that is, the male flower does not develop normally or aborts and, therefore, produces no live pollen.

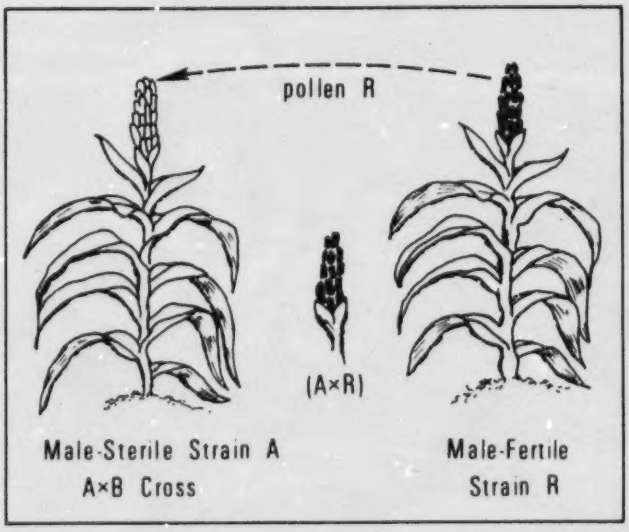
Male sterile lines in onions, sugar beets, sorghum, and corn have all but eliminated the emasculation process in making crosses. Hybrid seed and plants are produced by planting a certain number of rows of completely fertile plants and an adequate number of rows of sterile plants.

Male sterility is either a genetic or cytoplasmic characteristic. In some crops, gene action controls male sterility whereas in others it is controlled by sterile cytoplasm in the cell. Some strains of corn do not produce pollen because of inhibiting factors in the cytoplasm (the contents of a cell outside the nucleus).

Method used to produce hybrid grain sorghum seed - cytoplasmic male sterility:



Seed produced from A x B crossing in isolated field is planted to produce another male - sterile strain A plant.



Seed produced on from male - fertile strain R in isolated field is planted and is crossed with male - sterile strain A (A x B) cross. The hybrid single cross seed (A x R) which is also produced in an isolated field is sold to sorghum producers for planting. Strain A has non-pollen restoring genes whereas strain R has pollen restoring genes.

Other Techniques Used to Produce Hybrids

Crossing self-fertilized wheat, garden beans, soybeans, cotton, etc. requires a different technique from cross pollinating corn, because the male and female parts are completely separated on the corn plant.

Anthers may be removed on some self-fertilized plants by use of a needle, air or tweezers before they shed pollen. Hot water has been used to kill pollen on rice and grain sorghum in order to prevent self-fertilization. After emasculation of the flowers they are covered with bags to protect them against foreign pollen that may be transferred by insects or wind. Within a couple of days after emasculation, a sticky substance covers the stigma and pollen from the male parent (another plant) should be brushed or dusted on the stigma of the female plant.

A procedure used in crossing cotton is as follows:

When the cotton flower is mature enough for emasculation and crossing, the sepals and petals are cut away. At this stage the stigma is protruding from the tip of the flower.

A fine-pointed tweezer is used at this point to remove the stamens.

Ripe anthers are collected from a flower on the parent plant. A soda straw or tweezers may be used for this step.

If a soda straw is used, it is placed over the stigma of the prepared flower. The bracts are pulled up around the straw and tied. This procedure holds the straw over the style and protects the stigma from foreign pollen. Tweezers may be used to place anthers on the stigma and a bag may be tied over the flower.

Hybrid Crops

A list of several crops that are grown as hybrids are:

Cotton	Corn	Sorghum
Rice	Alfalfa	Soybeans
Barley	Wheat	Oats
Sugar beets	Flax	Cabbage
Onions	Cantaloupe	Castorbean
Millet	Spinach	Squash
Watermelon	Tomato	Eggplant
Sweet corn		

SUGGESTED STUDENT ACTIVITIES

1. Circle the correct answer.

   a. Before the Sixteenth Century crossbreeding of plants was done by nature. Yes No
   b. In the F_1 generation both dominant and recessive characteristics are expressed. Yes No
   c. The chromosome is a unit located on the genes causing inheritance characteristics. Yes No
   d. Chromosomes are contained in the cell nucleus. Yes No
   e. When the parents of the F plants are homozygous, the gametes of any one parent have identical gene alleles. Yes No
   f. In mitosis there are two successive nuclear divisions of the cell. Yes No
   g. The male and female parts are completely separated on the corn plant. Yes No
   h. Hybrid sorghum seed has been produced by using male sterile inbred lines. Yes No
   i. Male sterility in a plant is always controlled by gene action. Yes No
   j. There are no plant cells that can be seen by the naked eye. Yes No

2. Matching correct word/s with statement. Place correct letter in parenthesis by statement.

Word/s	Statement
a. Phenotype	( ) Contain genes with similar hereditary characteristics
b. Gametes	( ) The male flower does not develop normally or aborts
c. Homologous chromosomes	( ) External appearance of plant
d. Male sterile	( ) The egg and sperm of the F_1 have four combinations of genes
e. Protoplasts	( ) Crossing of plants of unlike genetic makeup
f. Chloroplasts	( ) Living part of a plant cell
g. Single hybrid	( ) Nonliving components of protoplast
h. Backcross	( ) Specialized plastids containing color or chlorophyll
i. Orgastic substances	( ) Plant A inbred plant x plant B inbred plant
j. Hybridization	( ) Hybrid crossed or bred to parent plant

3. Briefly discuss the following questions:

   a. Discuss how hybrid seed corn is produced.

b. Discuss a method used to produce grain sorghum seed.

c. List by steps and discuss briefly how cotton is crossed.

d. Discuss how a plant acquires certain characteristics.

e. What are the results of crossing the following two varieties of corn:

Variety A	+	Variety B
Excellent quality grain		Fair quality grain
Weak stalk		Strong stalk
Resistant to smut		Susceptible to smut
Resistant to drouth		Susceptible to drouth

RESULTS

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